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# Determinants of the Regional Demand for Higher Education

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# Determinants of the Regional Demand for Higher Education:

# A Gravity Model Approach

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**Abstract:** Studies on the determinants of the demand for higher education typically emphasize the relevance of socio-economic factors, but leave the spatial dimensions of the prospective students' university choices largely unexplored. In this study, we investigate the determinants of university entrance for Dutch high school graduates in 2000, and pay particular attention to the attractiveness of the university, both in terms of its accessibility and the educational quality of its programme. We combine cross-section data on the region of origin of the high school graduate and the university destination region for first-year students with regional and university characteristics in a production-constrained gravity model. The main finding of the study is that the behaviour of prospective students is governed by a negative distance deterrence effect and a downward rent effect, but a positive impact results from regional/urban amenities rather than from the educational quality of the university programmes.

**Keywords:** Demand for higher education, gravity model, education quality, agglomeration economies
**JEL-code:** I21, J24, O15, R23

## INTRODUCTION

Over the last few decades, the demand for higher education increased substantially in Europe. Between 1975 and 1997, Portugal showed the highest growth among the EU nations. The slowest growth occurred in Germany and The Netherlands, perhaps because participation rates were already high in these countries in 1975 (EUROPEAN COMMISSION, 2000, p. 104). Even so, the proportion of the Dutch 18-year old cohort attending university rose from 3% in 1950, to 17% in 1999 (CANTON and DE JONG, 2002, p. 7).

Several factors have been pointed out to explain the growing enrolment in higher education. Although initially demographic factors related to the baby boom were held accountable for the upsurge in higher education participation, economic determinants of the decision to continue studying after the secondary level were subsequently emphasised as well. Moreover, the decision process of prospective students has an obvious spatial dimension. The geography of student mobility is usually explained as an investment process in the human capital theory, or as a simple short-term cost-benefit assessment. Consumption motives have also been suggested as determinants of geographical student mobility, with the sensitivity of higher education demand to prices and income being among the pivotal factors.

In this paper we study the demand for higher education in The Netherlands using aggregate regional flow data, and include explanatory factors related to both the consumption and the investment motive for higher education. Some of the hypothesised theoretical aspects are not all that relevant for the Dutch higher education system. For instance, the role of income is most likely less pronounced because of the relatively low tuition fees, and the rather generous system of student support. The Netherlands has a binary higher education system, comprising universities and vocational/professional colleges, most of which are to a considerable degree publicly funded. Students pay tuition fees, which up until recently were centrally determined by the Ministry of Education. The tuition fees are identical in both tiers of the higher education system, and they have been rather low at a level of approximately 19% of the average direct cost of a university programme during the second half of the 1990s (CANTON and JONGBLOED, 2001, p. 22). Regular full-time students are eligible for publicly provided student support. The students are eligible for a base scholarship for the nominal duration of a higher education programme, which is either four or five years. The scholarship varies depending on the student's living arrangements (living with their parents versus living independently), and it is generally compatible with small part-time jobs. Depending on the student's own income and/or parental income, students can apply for an additional supplementary scholarship or a loan.

The role of income is potentially also mitigated by the availability of free public transport permits that students have been receiving since 1990. These permits allow for free travel on workdays and discount prices during the weekend. The reverse is also available as an option: free public transport during the weekend, allowing students to visit their parents, and reduced fares during weekdays. The availability of free transport permits obviously influences students' decisions on living arrangements and their location choice. Notwithstanding the availability of free travel permits, SCP (2000) observes that "young people are leaving home ever later, girls on average at 21, and boys at 23".

Another aspect that is typical for the Dutch higher education system concerns the relevance of rationing of supply. Prospective students have to meet minimum secondary education requirements fixed by the national government in order to be eligible for admission to the higher education system. In addition, higher education institutions can impose supplementary requirements regarding the courses that should be included in the student's high school programme, and professional colleges can even fix a broader range of entrance requirements (for instance, regarding skills, talent, or fitness for the profession). Generally, however, all students with a high school degree have access to higher education. In the professional tier of the higher education system rationing of supply occurs as a result of capacity constraints of the colleges and/or limitations of the labour market. In the university sector, however, rationing is non-existent, except for a limited number of profession-oriented programmes, such as medicine, dentistry, veterinary science, and information science, where the national government fixes the number of students based on prospective demand in the labour market (*numerus clausus*). Hence, for the university sector on which we will focus in this paper, demand and supply do not have to be studied simultaneously.

Finally, the spatial distribution of higher education institutions, and thus the geographical accessibility of the higher education system, may have important implications for the demand for higher education. Until the 1970s, a policy of geographical decentralisation of higher education based on the establishment of new universities was implemented in The Netherlands, mainly governed by spatial equity considerations (FLORAX, 1992). As a result of this process, the geographical accessibility of the university system is now relatively high and spatially equilibrated (FLORAX *et al.*, 2003).

Questions still abound, however. How relevant is the distance deterrence effect in students' choice behaviour? What is the significance of spatial price differentials, in particular regarding rental apartments? Are students' choice behaviours governed by considerations regarding the quality of educational programmes, or are urban amenities more relevant? These topics are of particular interest to policymakers and university administrators. Knowledge about these issues can assist policymakers in evaluating current higher education policies, such as the free travel permit programme. Concurrently, the knowledge can guide university administrators in their admission and marketing policies aimed at increasing the institution's scale and scope,[1] and it may play a role in the institution's discussion with local and regional policymakers regarding the quality of life in the city and its surroundings.

In order to address the above questions we calibrate a production-constrained gravity model for student flows from each region of origin to all destination regions harbouring a university. We consider the relevance of both university characteristics and regional features of university regions.

Given the abovementioned difference in rationing in the two tiers of the higher education system, and a general lack of data for professional colleges, we only investigate the university sector in this paper.

The present study differs from previous analyses in several respects. First, we use place-to-place data to estimate a gravity model for the Dutch situation in 2000. A gravity model calibrated with flow data is likely to be more adequate than a spatially aggregate model using stock data on university entrants. We are not aware of any other study on the Netherlands' higher education system that uses the flow perspective. In fact, most studies on the demand for higher education in The Netherlands do not model the spatial dimension (HUIJSMAN *et al*., 1986; KODDE and RITZEN, 1988; OOSTERBEEK and WEBBINK, 1995; CANTON and DE JONG, 2002), or they use aggregate stock data (FLORAX, 1987; FLORAX *et al*., 2003). Second, we include information about the overall quality of the university's teaching program in the model by means of a unique, composite index that combines information on all relevant university attributes. Third, we use a broadly defined concept of geographical student mobility that includes both student migration and commuting, whereas most studies have focussed solely on student migration.[2]

In the following section, we review the literature on geographical student mobility. The third section presents a theoretical and empirical gravity model, and describes our empirical strategy, data sources and explanatory variables. Subsequently, we present and discuss the empirical results, and conclude with the crucial findings of our research and possible directions for future work.

## DETERMINANTS OF THE MOBILITY OF UNIVERSITY STUDENTS

Over the past few decades an avalanche of studies on human migration has been generated; see, for instance, GREENWOOD (1975) and GHATAK *et al.* (1996) for reviews of the literature. Unequivocally, this literature points out two main reasons for migration. First, from a human capital point of view migration is treated as an investment, and the decision to move is taken in order to improve the workers' expected income and/or employment opportunities. Second, it can be viewed from a consumption standpoint, in which case people move because they look for better local amenities, such as parks, and recreational and cultural activities. These motives give rise to analysing geographic mobility in the context of a cost-benefit framework.

Migration in order to attend a university or college is part of this more general migration process, and is also guided by investment and consumption motives. The choice to move to a university city depends on benefits exceeding costs. Prospective students may move with the purpose of increasing future returns, implying higher future wages and/or higher employability. Alternatively, they may look for a better climate or a city with attractive amenities and leisure facilities, implying that there may be a consumption motive at stake as well.

► Table 1A and 1B about here ◄

Tables 1A and 1B provide an annotated overview of studies on the determinants of student mobility. We identify two different types of studies.[3] The first group of studies identifies who migrates and for what reasons. In general, this type of studies uses cross-sectional data on individuals; see Table 1A. ONO (2001) analyses migration among Japanese students, using a logit model with controls for students' social origins and demographic characteristics (gender and age), as well as for the quality and the number of universities. The main conclusion is that most of the university resources as well as the high-quality institutions are concentrated in large cities, and students move away from regions with low university resources to those with higher resources. ORDORVENSKY's (1995) study on individual and institutional determinants of students' choice of post secondary education, finds that students living closer to a given type of higher education institution are more likely to enrol in that type of institution. KJELLSTRÖM and REGNÉR (1998) include geographical distance as a regressor in their study on whether Swedish students enrol in university programmes of three years or longer, and they detect a negative effect for the 1967 cohort. DESJARDINS *et al.* (1999) confirm this finding, but show that the results are sensitive to the inclusion of variables related to the student's educational background. MCCANN and SHEPPARD (2001) consider migration to attend university as a first step in a sequential migration decision process, in which the next interrelated step is the decision to migrate to an employment location. They show that for the initial decision to move, better higher education institutions induce more migration, high intraregional availability of higher education reduces migration, and men are in general more mobile than women. In two related papers (MCCANN and SHEPPARD, 2002a,b) they further investigate the relevance of cultural and institutional factors, and of gender.[4] In sum, most studies document a negative effect for distance, although DESJARDINS *et al.* (1999) point to a study by Chapman, done in 1979, where distance does not have a significant effect on the decision to apply to a private university.

The purpose of the second group of studies (see Table 1B) is to identify the determinants of the rate of migration and to estimate the size of the student flows. Some studies of this type use states or regions as their unit of analysis, while others are based on institutions (universities or colleges). Both stock data as well as place-to-place flow data are used.

TUCKMAN (1970) is the earliest study considering interstate migration of college attendees in the US. He reports a positive effect of per capita income and the average price charged by within-state colleges on migration rates. If only voluntary migration (i.e., moves even although there is an in-state college) is considered, per capita income is not significant. However, in Tuckman's model both travel distance and travel cost are proxied by the number of public universities in a state. An extension of this model is provided by MIXON (1992a), who adds variables such as climate, and university quality and selectivity to the model for voluntary migration rates. Again, the effect of tuition is significantly positive, and no significant effect of per capita income is discernable. The higher the selectivity and the lower the quality of state colleges, the higher the voluntary out-migration rate. MIXON (1992b) extends the analysis even further, by including political variables in a recursive system of three equations dealing with the state's higher education budget earmarked for institutional support, the tuition level, and out-of-state migration, respectively. The main results for tuition and institutional quality remain unchanged, however.

FLORAX *et al.* (2003), in their comparative study for The Netherlands, the UK and Sweden, explain variations in the number of first-time entrants of each region, using regional characteristics in a model that is estimated for both university and non-university regions. They pay attention to the spatial accessibility of higher education institutions by means of a regional potential index revealing the impact of distance between the student's region of origin and all universities, taking into account size differences in universities. The index has no significant effect on the regional demand for university education, neither in university regions nor in non-university regions, except for the 1970s and 80s in Swedish university regions; see WIKHALL (2001) for more detailed results on Sweden.

From the studies employing institutions (universities and colleges) as the unit of analysis, MIXON and HSING (1994a) improve the previous models by TUCKMAN (1970) and MIXON (1992a,b). The percentage enrolment of out-of-state students in colleges and universities, and tuition levels are explained simultaneously. Factors such as small class size, college selectivity, successful athletic programs, and availability of cultural alternatives contribute to attracting students to universities and colleges. This study thus lends support to both the human capital and consumption theories. The results are very similar to the one-equation results presented in MIXON and HSING (1994b).

BARYLA and DOTTERWEICH (2001) further improve the above type of model by including all universities in the US, rather than a random sample. They use a two-stage model, in which tuition for non-resident students is explained in the first stage, and subsequently used to analyse non-resident enrolment. The model is estimated for four different sub-areas of the US, and shows that selective institutions uniformly attract more non-resident students. The university's socio-economic environment is, however, not consistently of relevance across the four different areas.

Finally, within the second type of studies focussing on migration rates some studies are based on place-to-place data. Using data on student migration flows from origin-states to the state of New York, KYUNG (1996) finds that the number of enrolments decreases with distance. MCHUGH and MORGAN (1984) already performed a similar analysis considering all possible destination regions. They model the student's migration decision as a function of economic and environmental factors, institutional variables (including institutional quality) and distance. Distance is operationalized in two distinct ways, 'as the crow flies' and as the mean distance between the origin and all other states, in order to capture the impact of intervening alternatives on student migration. The Euclidian distance variable has a significantly negative effect on migration. Moreover, the more intervening alternatives exist (i.e., the lower the mean distance between the origin and all other states), the lower the student flows. The authors also show a non-uniform effect of institutional quality on student migration: while high prestige and selectivity is important for some students, others prefer less selective colleges.

ISHIKAWA (1987) applies a production-constrained competing destinations model to data on university enrolments in Japanese prefectures. He uses a production-constrained gravity model with an additional variable accounting for the accessibility of each university compared to all other universities.[5] The typical distance variable has an overall negative effect on student flows. The model is also calibrated with specific parameters for each origin-region, and the results of this specification confirm the aforementioned distance deterrence effect for all regions. The accessibility measure shows a process of university choice dominated by agglomeration forces, meaning that the probability of an individual choosing a given university increases with the proximity of that university to all other universities.

In sum, the spatial dimension has been included in several studies concerning students' behavioural choices vis-à-vis higher education participation. The influence of distance has been incorporated in studies dealing with the determinants of student mobility, and in studies considering student migration rates and flows. By and large the results of those studies corroborate the prevalence of a negative distance deterrence effect. Several other aspects, such as socio-economic and institutional factors, have been taken into account as well. In the next section, we build on this existing body of research by considering a modified gravity model that controls for university characteristics as well as their geographical location.

## A GRAVITY MODEL OF PROSPECTIVE STUDENT MOBILITY

Economic theory is based on the assumption that individuals maximise their well-being. In a rational choice perspective, students compare all possible universities and choose the institution and study programme that fits their needs best. The prospective student's decision to move over geographic space, either in terms of migration or commuting, can be described using spatial interaction models.

### *Structural modified gravity model*

In the Netherlands' higher education system the demand for university education is generally satisfied. Since there is no *numerus clausus* for most study programmes, universities do not have capacity constraints, and all eligible students can enter the university and the study programme of their choice, we can expect there to be no full resource utilisation. We can therefore describe $S_{ij}$, the distribution function of student flows from region $i$ to university $j$, as:

$$S_{ij} = A_i O_i h(d_{ij}), \tag{1}$$

where

$$A_i = \left[ \sum_{j=1}^{r} h(d_{ij}) \right]^{-1} \tag{2}$$

is a balancing factor, $O_i$ the total number of university students in region $i$, measuring origin-region propulsiveness, and $h(d_{ij})$ a deterrence function that captures the resistance to mobility between $i$ and $j$ depending on the spatial separation between $i$ and $j$, measured by the distance $d_{ij}$. This structural model is usually referred to as the production-constrained gravity model. It can be extended to include prior information on the distribution of student flows, such as university features, $w_{kj}$, resulting in the more general model:

$$S_{ij} = \left( \prod_{k=1}^{p} w_{kj}^{\alpha_k} \right) A_i O_i h\left(d_{ij}\right), \tag{3}$$

where

$$A_i = \left[ \sum_{j=1}^{r} \left( \prod_{k=1}^{p} w_{kj}^{\alpha_k} \right) h\left(d_{ij}\right) \right]^{-1}, \tag{4}$$

$w_{kj}$ are university characteristics, possibly stacked in a matrix **W**, and the parameters $\alpha_k$ represent elasticities of student flows with respect to university features.

Some authors have argued that production-constrained models produce biased distance-decay parameter estimates and inaccuracies in the prediction of the interactions; see, for instance, FOTHERINGHAM and O'KELLY (1989) and FOTHERINGHAM *et al.* (2001). These problems are alleviated when the so-called competing destinations model is used. The modification consists of adding a centrality index $c_j$ that describes the competition between destinations:

$$c_j = \sum_{m=1}^{n} \frac{P_m}{d_{mj}}, \tag{5}$$

where $d_{mj}$ is the distance between university $m$ and university $j$, and $P_m$ is a measure for the attractiveness of destination $m$. The centrality index captures the competition that each destination faces from all other destinations. In practice, introducing the centrality index constitutes a way to make the vector of university characteristics more precise, and it can hence be seen as one of the variables in **W**.

It is possible that students do not consider all potential universities when making a decision. It may be that they first select a cluster of universities and only evaluate the alternatives within that cluster. By including the centrality index, it is possible to capture the effects of hierarchical destination choice. Consider the centrality index is $w_1$ in equations (3) and (4), with associated parameter $\alpha_1$. If $\alpha_1 > 0$, agglomeration forces are present, and destinations in close proximity to other destinations are more attractive. If $\alpha_1 < 0$, competition effects are present, implying that destinations in close proximity to other destinations are less attractive. Finally, if $\alpha_1 = 0$, hierarchical decision-making is not relevant in explaining destination choice.

*Empirical model and empirical strategy*

Several choices still need to be made in order to arrive at a feasible empirical model. The first choice relates to the centrality index. We operationalize $P_m$, measuring the attractiveness of each destination, by means of the total number of students at each university. Fig. 1 shows the computed values for the centrality index. The universities in Delft (TUD), Leiden (LEI) and Rotterdam (EUR) are the most central universities, whereas the least central universities are located in Groningen (RUG), Twente (UT) and Maastricht (UM).[6]

► Fig. 1 about here ◄

The second choice relates to the spatial separation measure to be used. Distance, travel time and travel cost are all potential separation measures distinguishing the 'distance' between origin and destination regions. In general, the longer the distance to the university, the higher the financial and social cost students experience. Students who decide to move do not only face pecuniary costs but also costs associated with the establishment of new social and interpersonal relations.[7] The financial cost of entering the university system includes, among other things, travel cost for commuters and moving and housing cost for those who relocate. As Dutch students do not carry the monetary burden of travelling because of the free travel permit and because they are all eligible for student support, we refrain from using travel cost as the spatial separation measure.

The resulting choice between travel time and distance is governed by various considerations making that, in the end, we decided to use mere distance. First, the choice of a transportation mode (or a combination of modes) for which travel time would have to be computed is not straightforward. Public transportation is provided free of charge, but students may still decide to use their private car or their bicycle, the latter constituting the traditional means of transportation of Dutch students. Second, no reliable travel time data can be obtained for travel by bicycle. Third, KJELLSTRÖM and REGNÉR (1998) show that using travel time by car, as compared to a simple physical distance measure, does not increase the explanatory power of the model. Finally, RIETVELD *et al.* (1999) show that the correlation between travel time and distance is fairly high.[8] Therefore, $d_{ij}$ refers to road distances in the remainder of this study.

A final choice concerns the functional form of the distance decay function, $h(d_{ij})$ in equations (3) and (4). Since we expect long distances to dominate, we enter distance in the gravity model by means of a power form deterrence function, $h(d_{ij}) = d_{ij}^{\beta}$. FOTHERINGHAM and O'KELLY (1989, pp. 12-13) observe that there is actually "a reasonable widespread consensus that the exponential function is more appropriate for analyzing short distance interactions [...] The power function, conversely, is generally held to be more appropriate for analyzing longer distances interactions”. As a result, the estimated distance-decay parameter is scale independent, and high cost movements (over long distances) are not overestimated, as would be the case for the exponential function. The empirical form of the general gravity model can therefore be written as:

$$S_{ij} = \left( \prod_{k=1}^{p} w_{kj}^{\alpha_k} \right) A_i O_i d_{ij}^{\beta} \text{ where } A_i = \left[ \sum_{j=1}^{r} \left( \prod_{k=1}^{p} w_{kj}^{\alpha_k} \right) d_{ij}^{\beta} \right]^{-1} \quad (6)$$

In order to calibrate the empirical version of the production-constrained gravity model by means of a regression, we linearise equation (6) following the procedure suggested in FOTHERINGHAM and O’KELLY (1989, p. 45):

$$\ln S_{ij} - \frac{1}{n}\sum_{j=1}^{n} \ln S_{ij} = \sum_{k=1}^{p} \alpha_k \left( \ln w_{kj} - \frac{1}{n}\sum_{j=1}^{n} \ln w_{kj} \right) + \beta \left( \ln d_{ij} - \frac{1}{n}\sum_{j=1}^{n} \ln d_{ij} \right) + \varepsilon_{ij} \quad (7)$$

where $\varepsilon_{ij} \sim \mathrm{N}(0, \sigma_{\varepsilon}^{2})$ is a random error term that captures network variables not explicitly included in the model specification.

The model in equation (7) is the basis of the empirical strategy to be implemented in the next section. Initially, the model is calibrated with both university characteristics and aspects related to the university’s location as regressors. We refer to this model as the ‘baseline model’. Because the unit of analysis is a rather arbitrarily delineated administrative region, spatial effects may be present in the data; see, for instance, FLORAX and NIJKAMP (2003) for more details on spatial effects. Subsequently, we correct for spatial heterogeneity by estimating the same model, including origin-specific distance coefficients, $\beta_i$. Finally, because the educational scope of the university may be relevant in the decision-making of students we also calibrate the same model with university-specific distance parameters, $\beta_j$. This enables us to distinguish between universities with a rather local catchment area and nation-wide universities with unique teaching programmes, either according to subject or to educational philosophy.

*Data sources and variable description*

The spatial level of aggregation is the COROP-level with 40 regions, which is equivalent to the European NUTSIII level. Fig. 2 shows the location of universities and the percentage first-year university students as to the total number of university entrants according to region of origin. It is easily verified that university regions on average contribute more to the national demand for first-year university education than non-university regions. However, this is obviously confounded with population density, especially in the densely populated East-West band in the middle of the country, in which the major city conurbations of Amsterdam, Rotterdam, Utrecht, Arnhem and Nijmegen are located. Fig. 3 presents regional participation rates, defined as the number of first-year entrants per 1,000 in the population. It shows that the spatial distribution is fairly uniform about the mean participation of 1.87%; the standard deviation is 0.31. The areas with the highest participation rates are the northern part of the Randstad area and the hinterland of the city of Groningen. Remarkably enough, the metropolitan areas of Amsterdam and Rotterdam have a relatively low participation rate.

► Fig. 2 and 3 about here ◄

Instead of the above regional perspective, the institutional perspective centring on universities as the unit of observation is relevant as well. Fig. 4 therefore gives the market share, defined as the percentage of first-year students as to the total number of first-year students, of each institution. The Figure shows that the traditional full-fledged universities have the largest market shares, whereas the specialised technical universities (TUD, TUE and UT), the agricultural university (WUR) and the more recently established universities covering a limited number of disciplines (KUB and UM) obtain the smallest market shares. The market shares are generally highly correlated with the overall size of the university in terms of the number of students.

► Fig. 4 about here ◄

The Netherlands has 13 funded universities, one designated university and the Open University. The main difference between the designated institution and the funded institutions is that the designated institution is privately funded, and not eligible for public funding. Given data availability we only consider the 13 funded institutions, with the geographical locations as provided in Fig. 2. The model calibration is thus based on 520 (= 40 × 13) flows, corresponding to all possible flows between each of the 40 regions of origin and the 13 university regions.

For most of the variables, data are obtained for the year 2000 by combining information from various datasets. A cross-section dataset for first-time university entrants bought from the Central Office for Higher Education Application (IBG, Informatie Beheer Groep), is combined with regional information on university regions from Statistics Netherlands (CBS, Centraal Bureau voor de Statistiek) and characteristics of the universities made available by the Association of Dutch Universities (VSNU, Vereniging van Samenwerkende Nederlandse Universiteiten). The university attributes that we need to construct the university quality index are taken from the ELSEVIER (1999) survey. Table 2 shows the descriptive statistics for the continuous variables used in the analysis as well as the hypothesised direction of the effects.

► Table 2 about here ◄

The dataset on first-year applicants includes all students who register at a university for the first time in 2000. Students who transfer to another higher education institution or change study program at the same university are excluded from the analysis. The dataset contains information on gender, the student's residence at the moment of application and the university to which he or she applies. We use the data to calculate the number of flows of prospective students between the region of origin and the university regions. The ultimate dataset contains 30,037 individual movements assigned to (40 × 13) cells of the flow matrix. Only eight cells have zero movements, 954 is the largest flow, and the average size of the flows is 58. Since $S_{ij}$ in equation (7) must be positive, we added one to the zero flows, because the flows recorded are generally integer and one is the closest approximation to zero (FOTHERINGHAM and O'KELLY, 1989, p. 49).

We operationalize the distance impediment variable with distance over the road from each region to each university as measured between the regional foci with the highest population density in each COROP region. Intrazonal distances are computed as $d_i = (\pi - 1)/\pi \cdot \sqrt{s_i / \pi}$ , where $s_i$ is the area of region $i$, measured in squared meters (see RIETVELD and BRUINSMA, 1998), although strictly speaking the formula assumes that regions are circular, and all zones are equally intensively used.[9] Following the results of earlier studies, we expect distance to deter student mobility over space.

In addition to distance we make use of five additional explanatory variables: the quality of the university (in particular its teaching programme), the number of programmes offered, the centrality index discussed above, the level of urbanisation and an apartment rent variable.

Returns to educational quality and prestige of a school is usually assessed through the student-teacher ratio, average students per class or per school, students' performance as measured by standardized tests, etcetera (CHECCHI and JAPPELLI, 2002). Although the student-teacher ratio is available for the Dutch university sector, we also try to extract data from a broader spectrum of information on the quality of educational university programmes from an annual survey conducted by weekly magazine ELSEVIER (1999). In 1999, 20 study programmes were evaluated for the Elsevier ranking by interviewing a stratified sample of about 6000 university students. The respondents were asked to give points from 1 (for extremely poor) to 10 (for extremely good) to the quality of their academic studies with respect to teaching facilities (computer rooms, seat availability), curriculum (topics in the program and its relevance), tutors and lectures (supervision, office hours, lectures and syllabus quality), teaching quality (research skills, lectures), examination (connection between lectures, study materials and exams), and communication between the school and the student. We combine the scores on the attributes in a composite overall index for educational quality of the university:

$$Q_j = \prod_{k=1}^{K} \left( 0.5 + \frac{e^{(y_k - \mu_k)/\sigma_k}}{1 + e^{(y_k - \mu_k)/\sigma_k}} \right), \tag{8}$$

where $y_k$ are different university attributes, and $\mu_k$ and $\sigma_k$ are the mean and the standard deviation of each attribute, respectively.[10]

In order to assess whether the use of the quality index will lead to valid conclusions we perform two cross-validation checks. First, we plot the index $Q_j$ against the student-teacher ratio, which is frequently used as a quality indicator. As shown in Fig. 5, we only find a negative relationship between the quality index and the student-teacher ratio if we exclude the outlier (Wageningen Agricultural University and Research Centre). In that case, the correlation between the quality index and the student-teacher ratio is –0.58. Second, we regress the quality index on the remaining exogenous variables of the gravity model including a constant, and find that the constant is not significantly different from zero, but the other variables are.[11] Moreover, the bivariate correlation coefficients among the explanatory variables indicate that the quality index is highly correlated with the centrality index ($r$ = –0.76), which may lead to collinearity problems in the estimation of the regression model. The corresponding correlation with the student-teacher ratio is substantially lower ($r$ = 0.30). As a result of the two validity checks, there may be some doubt as to whether the multidimensional quality indicator is fully appropriate and whether it is feasible to use it along with highly correlated covariates. We therefore estimate the models using either the composite quality index or the student-teacher ratio as an indicator for the quality of teaching programmes.

► Fig. 5 about here ◄

The expected sign of the quality variable is a priori unclear. Some studies have documented a positive effect of school quality on the rate of return to education and employability. For instance, BREWER *et al.* (1999) find that attending an elite private college has a significant economic return. As a consequence, one would expect that if students' choice behaviour is governed by investment motives, educational quality is important, and hence shows up with a positive sign. There is evidence as well, however, that prestige, which is strongly correlated with university quality, explains only a small part of first-time undergraduate migration (ABBOTT and SCHMID, 1975). Moreover, MCCANN and SHEPPARD (2002a) find that quality differentials among universities are not significantly different from zero in their model pertaining to Scottish students.

Next to university quality, we consider two other university related variables in the analysis. One is the number of study programmes per university in order to account for economies of scope. The data were provided by VSNU (2000), and we expect this variable to have a positive impact on student flows (although the causality can actually be reverse as well). The other is the centrality index, already discussed above. There is no a priori expectation on whether the agglomeration or the competition effect is dominant, or that hierarchical decision-making is actually irrelevant.

Apart from the university-related variables we include two variables that are indicative of salient characteristics of the university regions. It has been shown that location-specific amenities and cost of life differentials are important determinants of migration (GHATAK *et al.*, 1996). We therefore include an urbanisation index, adopted from CBS (2000a,b), as a proxy for cultural and social diversity of university regions. We expect the urbanisation index, which has been operationalized as population density, to have a positive sign. For lack of reliable regional data on consumer prices we incorporate only one variable as an indicator for cost of life differentials. A major part of student budgets is typically spent on housing. As rental rates for student apartments and student rooms are particularly cumbersome to attain, we use data on the so-called basic rent for houses obtained from CBS (2000c) as the best proxy. We expect rental rates to be negatively correlated with student mobility.

## MAIN FINDINGS AND DISCUSSION

In this section we present the estimation results for the operational production-constrained gravity model given in (7) above. We employ two different perspectives, with the first focussing on regional differences in the distance deterrence effect, and the second having an institutional perspective with concurrent attention for the extent to which universities serve a national or a regional market. Within each perspective, the quality of educational programmes is operationalized using either the composite quality index or the student-teacher ratio. The results are presented with White-adjusted standard errors because the Breusch-Pagan heteroskedasticity test, evaluated using the ordinary least square estimator, is persistently rejected.

*Regional perspective*

We show the estimation results for the baseline models in three columns in Table 3. The simplest production-constrained gravity model merely includes distance between the students' region of origin and the university region as destination, and is given in the left-hand column under Specification I. Conforming to theoretical expectations distance has a negative effect on student movements over space. Higher distances deter students from going to those universities. DESJARDINS *et al.* (1999) argue this can be due to students having a better knowledge of nearby universities, socialising with friends and family remains feasible at close-by institutions, and costs may be lower, in particular because there may be no need to acquire independent housing.

► Table 3 about here ◄

The distance deterrence effect is robust in sign and magnitude across different specifications; see specifications II and III in Table 3, which include the other covariates, with either the composite index (Specification II) or the student-teacher ratio (Specification III) for the quality of educational programmes. Students are attracted by locally and regionally supplied amenities for leisure and socialising, as operationalized by the level of urbanisation. The outstanding finding refers, however, to the magnitude of the rent elasticity, which is highly elastic at a level of approximately –5.5 in the specification that is least suspect to multicollinearity problems (Specification III). Most likely, this result reflects the relative importance of rent in the budget of Dutch university students. The magnitude of the estimated rent elasticity overrides all other estimated elasticities of hypothesised effects. As an empirical background of this result it is important to note that the market for student residences is tight in several university cities. High rents may therefore be a proxy for long waiting lists that discourage students to move to these cities.

Of the institutional variables, the scope of the university, in terms of the number of available teaching programmes, is significant, implying students are attracted by universities with a more diverse courseware. Surprisingly, we find a negative effect for the quality of the teaching programmes, operationalized with the composite quality index.[12] Quality, as measured by the student-teacher ratio does have the correct sign, but it is not significantly different from zero. These findings are an indication for consumption motives rather than investment motives dominating the choice behaviour of the Netherlands' students, which is at odds with what has been found in the literature; see MIXON (1992a,b), MIXON and HSING (1994a), and ONO (2001). A partial explanation for this finding derives from the relatively small differences in the quality of universities in The Netherlands due to a long egalitarian tradition in education. The latter contributes to a rather uniform quality of high school graduates, but it also stimulates the prevalence of a rather uniform system of university education with relatively low and institutionally uniform tuition fees and a homogeneous system of university budgeting by the national government.

Finally, the negative and significant effect of the centrality index reveals that students' choices are made in a hierarchical fashion, and suggest the presence of an institutional competition effect. Hence, agglomeration effects resulting from spatial clustering in the location of universities, such as in the Randstad area, are negative because they are incorporated in the students' choice behaviour as competition among proximate institutions.

► Fig. 6 about here ◄

Subsequently, we account for spatial heterogeneity in the distance deterrence effect by calibrating a model with region-specific coefficients for the distance variable. For reasons of space, we do not show the regional coefficients in Table 3, but we provide a map of the distance decay elasticities in Fig. 6. Except for the coefficient of the centrality index, which is slightly larger in absolute value under the region-specific distance deterrence regime, the coefficients do not change between the uniform and the region-specific distance deterrence variants. The distance decay elasticity is on average –1.56 for the COROP regions, with a standard deviation of 0.67 in Specification III, and hence slightly higher in absolute value as compared to the uniform distance decay elasticities in the baseline scenarios. Fig. 6 shows that the distance decay elasticity is highly elastic in the more remote areas of the country, specifically in the rural peninsula's of Zeeland in the South-West, and the rural areas in the north of Noord-Holland and in Friesland. Overall the regional demand for university education is elastic: the distance decay elasticity is greater than –1 in absolute value for 33 out of 40 regions. The central-eastern part of the country shows inelastic demand for university education according to distance. Three out of five of those elasticities are not significantly different from zero. The areas with inelastic demand are largely relatively remote rural areas, although they comprise medium-sized cities such as Enschede, Nijmegen and Arnhem, but most likely the attitude of prospective students and the relatively good transportation connection to the Randstad area go a long way in explaining this phenomenon. Moreover, of the three universities located in this part of the country, one is a technical university and another one is the agricultural university, which may also influence the results.

*Institutional perspective*

Apart from the prevailing regional differences described in the preceding subsection, institutional differences are therefore potentially of interest as well. Particularly, the extent to which a university serves a national or a regional market is relevant for several reasons. First, it ties on to the geographical decentralisation policy of higher education institutions propelled by the Dutch national government (see FLORAX, 1992). Second, it provides the necessary spatial context for the evaluation of policy measures geared towards the facilitation of student travel (free travel permits). Third, knowledge about the catchment area is relevant to university administrators for marketing purposes.

► Table 4 and Fig. 7 about here ◄

Table 4 therefore provides the results for the production-constrained gravity model with university-specific distance coefficients for the three alternative specifications. For ease of interpretation, Fig. 7 shows the university-specific distance decay coefficients of Specification III. The main implications of the estimation results remain unaltered: the sign and the magnitude of the coefficients of most variables are by and large similar, although the absolute value of the centrality index is substantially smaller in Specification III. The quality index for the teaching programmes is again negative and significant for the composite index operationalization, and negative but insignificant for the student-teacher ratio operationalization. In addition to the above-mentioned reasons for this result one may also speculate that prospective students are maybe not sufficiently aware of quality differences between teaching programmes[13] and/or their expectation of the returns to school quality may be that it is negligibly small.

The university-specific distance decay elasticity of the demand for first-year university education is greater than one for most universities, implying that generally the demand is elastic and hence most universities have a regionally demarcated catchment area. It is remarkable that the ‘regional orientation’ of small institutions, such as Tilburg University (KUB) and Eindhoven University of Technology (TUE), is not all that much different from large institutions, such as the University of

Amsterdam (UvA) and the centrally located University of Utrecht (UU). Contrary to what one may be inclined to believe, it is not the university that is located in the geographical midpoint of the country (the University of Utrecht, UU) that has the most distinct national catchment area. Instead, smaller specialised universities, in particular Wageningen Agricultural University and Research Centre (WUR), Delft University of Technology (TUD), and Maastricht University (UM) have national recruitment markets. The main reasons for this phenomenon are the specialised nature of the teaching programmes in Wageningen and Delft, and the unique educational philosophy of Maastricht University that offsets its 'natural' regional orientation given its remote location.[14]

## CONCLUDING REMARKS

University accessibility is a fundamental aspect of higher education systems and it may impact student flows over space. We use a spatial interaction model allowing for the distinction between spatial and non-spatial aspects to assess the determinants of student mobility in The Netherlands, in 2000. The empirical results for prospective university students show trade-offs between the constraints imposed by distance and the attraction of universities and regions where universities are located.

A key finding of our study is that the choices of prospective university students are mainly guided by consumption motives, while investment reasons are not predominant, because the quality of educational programmes does not play a significant role in their choice behaviours. Agglomeration economies, in effect leading to a relative abundance of socio-cultural and leisure facilities, and the scope of the university in terms of program diversity exert a positive influence on the demand for education by prospective university entrants. Both distance and apartment rent deter the geographic mobility of students. The regional demand for higher education is generally inelastic with respect to distance, with the more remote areas in the south-west and the north of the country having the highest (absolute) value of the elasticity. Inelastic demand occurs in the central-eastern part of the country, although this effect may be partly due to the specialised nature of some of the universities (specifically Twente and Wageningen) located in that part of the country. The relevance of the latter also becomes apparent in the analysis allowing for heterogeneous distance decay elasticities for different universities. Some of the more specialised universities, either in educational programmes (the technical university in Delft and the agricultural university in Wageningen) or in educational philosophy (Maastricht), have a national recruitment market, whereas the others institutions have a more regional orientation.

The empirical results indicate that, in general, there is no need to for Dutch higher education policy to focus on extending the geographical decentralisation of the university system. Instead, one may speculate that there may be some merit to geographical concentration of some of the teaching programmes. Although the region-specific distance decay elasticity is generally greater than one, specialised institutions are able to draw students from further away. Specific attention is, however, warranted for relatively remote areas in Friesland, Zeeland, and the northern part of North-Holland, where the effect of distance of the regional demand for university education is the most pronounced. This is relevant for national higher education policy as well as for university administrators. In the context of the former, efficiency and equity considerations may call for a specific policy targeted at increasing the student flows originating from relatively remote areas. At the same time, university administrators may take advantage of the fact that marketing efforts directed specifically at those areas is likely to be attractive because the potential for increasing demand is relatively high in these areas. Finally, the empirical results imply that policy measures geared towards an increase in the demand for higher education should not primarily focus on geographically extending the opportunities for education (perhaps with the exception of the abovementioned areas), but rather at lowering the burden of rental cost. In particular, changes in taxation laws focussing on tax breaks for taxpayers providing student boarding may be expected to be highly effective.

Our research can obviously be extended in various ways. It would be particularly useful to be able to incorporate information on commuting versus migration of students, to include the professional sector of higher education, to further investigate the measurement and relevance of the quality of educational programmes, and to focus on the impact of supply constraints. There is a need for such research with respect to The Netherlands, but also an international comparative study would provide useful insights in an era where the Bologna treaty signals that national governments in Europe are aiming for an intensified integration among the national systems of higher education. Finally, there are obvious limits to what can be achieved using *aggregate* spatial data. Future research geared towards investigating prospective students' choice behaviours using *individual* georeferenced data is likely to lead to more detailed knowledge with clear policy relevance.

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## NOTES

[1] Note that the number of students is an important determinant of university funding provided by the national government. The government allocates 37% of the teaching budget across universities as a fixed lump sum per study programme, but the number of students graduating in a given year determines 50% and the number of first-year students 13% of the teaching budget (CANTON and JONGBLOED, 2001, p. 29). Hence, 63% of the total budget for teaching depends on the number of entrants and on students' performance.

[2] This "double" focus seems the more reasonable since The Netherlands is a small-scale country with 13 universities in an area of only 40,000 km$^2$. This implies that each 100×100 km grid harbours on average approximately three universities. The longest possible travel distance between a municipality and the nearest university is only slightly over 100 km. Since public transport is in effect gratis, students can continue to live with their parents and easily commute to the university on a daily basis.

[3] Related studies with a somewhat different outlook include geographical studies such as HOARE (1991) and BATEY *et al*. (1999), and a sociological study by ABBOTT and SCHMID (1975).

[4] Because MCCANN and SHEPPARD (2002b) is still very much work in progress, we have not yet included this study in Table 1A.

[5] Similarly, ULLIS and KNOWLES (1975) investigate intrastate migration of Washington college freshmen. The paper focuses on determining the appropriateness and predictive ability of the gravity type model. We do not include this study in Table 1B, because the outlook is methodological, rather than substantive.

[6] The centrality index given in equation (5) includes the cases where $m = j$, implying the use of a measure for intrazonal distance. This does obviously introduce a certain degree of arbitrariness, because intrazonal distances depend on the size of the administratively delineated regions. We have experimented with various definitions of the intrazonal distance measure, and eventually chose to keep it constant across university regions at the level of the average minimum distance of each region to its closest neighbour across all COROP regions. Alternative definitions of the centrality index do not have a strong influence on the empirical results.

[7] We observe in passing that some students may actually also incur non-pecuniary benefits based on distance. For instance, some students may want to relocate far from the parental home in order to be able to cut existing social and family ties.

[8] They report a correlation of 0.95 with travel time measured by means of route planners, and 0.80 with reported travel times.

[9] We actually calibrated the models using various alternative definitions for intrazonal distances: (a) the formula given in the main text, which boils down to:

$$d_i = 0.68 \cdot \sqrt{s_i / \pi}\ ,$$

(b) a similar formula based on slightly different assumptions suggested by RICH (1980),

$$d_i = 0.50 \cdot \sqrt{s_i / \pi}\ ,$$

and real-world measures such as (c) half the minimum distance to the closest region and (d) half the average distance to all contiguous regions. The main results reported in the sequel are, however, not influenced by these different measures for intrazonal distances.

[10] For each university, a limited number of study programmes is evaluated, as a rule those with many students. For each university and attribute we compute the average score over the different study programmes, weighted by the number of students in that specific programme as to the total number of students of the programmes evaluated at a specific university. The quality index is strictly positive, which enables us to use it in the logarithmic specification, and varies between 0.5 and 1.5 per attribute; see PORTELA (2001) for more details.

[11] This validity check is adopted from CHECCHI and JAPPELLI (2002), who apply a similar procedure.

[12] This finding is robust across various operational definitions of the composite quality index. For instance, using the mean value over all attributes instead of the composite index in (8) also results in a negative effect of quality, with the signs and magnitudes of the other variables not being affected.

[13] Note that the quality index reveals the evaluation of current students rather than prospective students; see the subsection on data sources and variable description.

[14] Maastricht University is known for its Problem-Oriented-Education (PGO, Probleem-Gestuurd-Onderwijs). PGO's main feature is that students work on assignments and discuss the materials in small groups under close supervision of a tutor.

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*Table 1A. Annotated overview of studies on the demand for higher education using individual data*[1]

| Study | Year data | Unit of analysis | Dependent variable | Results |
|---|---|---|---|---|
| ORDOVENSKY (1995) | 1980 | High school students, US | Choice post-secondary alternative (vocational and academic programmes at colleges and universities)[2] | Direct cost to family income (·), distance to the nearest institution of each type (+/·/–), peers going to college (+), peers going to other post-secondary school (·), vocational track high school (–), academic track high school (+), family owns home (+), unemployment (·), gender (+), race (+), ethnicity (+), grade point average (+), standardized test score (+), tuition/income ratios (·/+/–), parental educational level (+/+), parental vocational occupation (–/+) |
| KJELLSTRÖM and REGNÉR (1998) | 1948, 1953, 1967 | Individuals from cohorts, Sweden | Choice to enrol in ≥3 year university programme | Parental occupation (+), parental educational level (+), individual ability (+), distance (– 1967 cohort/· others) |
| DESJARDINS *et al.* (1999) | 1995 | Applicants to land-grant universities, US | Choice to apply | Gender (·), marital status (·), siblings (–), tuition reciprocity (–), age (+), size of town (–), distance (?), competitor institution (–), public high school (–), college prep courses (+), ACT scores (–), high school size (–), ability (+), no tuition preference (+), public college (+), size college (+), work plans (–), apply for aid (–), post-baccalaureate degree (+), high school prep requirements (?), high school extra curriculum activities (?), college major occupational choice (?) |
| ONO (2001) | 1995 | Individuals 20–64 years, Japan | Choice to move | Colleges offering major (+), quality of college (+), competitiveness college (+), private university (–), father's occupational prestige (·), siblings (·), gender (·), age (·), city size (–) |
| MCCANN and SHEPPARD (2001) | 1995, 1996 | Graduates of 1995 and 1996, UK | Choice to move[3] | Gender, male (+), unemployment orig. (·), unemployment dest. (–), number of institutions (–), economic activity orig. (+), economic activity dest. (·), population density orig. (–), population density dest. (–), wage orig. (–), wage dest. (+), quality (+), postgraduate (–), grade awarded (·/+/+/+), distance from London orig. (–), distance from London dest. (+), Wales (+), Scotland (–) |
| MCCANN and SHEPPARD (2002a) | 1995, 1996 | Graduates of 1995 and 1996, Scotland | Choice to move[3] | Unemployment orig. (·), unemployment dest. (+), number of institutions orig. (–), number of institutions dest. (–), economic activity orig. (–), economic activity dest. (+), population density orig. (·), population density dest. (–), wage orig. (·), wage dest. (·), quality (·), postgraduate (–) |
| | | Graduates of 1995 and 1996, Wales | | Unemployment orig. (+), unemployment dest. (–), number of institutions orig. (·), number of institutions dest. (–), economic activity orig. (–), economic activity dest. (–), population density orig. (+), population density dest. (–), wage orig. (–), wage dest. (+), quality (+), postgraduate (–) |

*Notes:*
1. Statistically significant variables appear with the sign in parentheses. Variables that are not significant are indicated using the symbol "·". The symbol "?" is used for a variable that is operationalized by means of dummies not showing a uniform direction of the effect. Multiple results refer to similar variables.
2. We only report the results for the probability of enrolment in a 4-year college or university programme, and discard information on vocational schools and 2-year colleges with vocational or academic programmes.
3. Results refer to the migration decision of prospective students.

*Table 1B. Annotated overview of studies on the demand for higher education using aggregate spatial or institutional data*

| Study | Year data | Unit of analysis | Dependent variable | Results |
|---|---|---|---|---|
| TUCKMAN (1970) | 1963 | US states | Gross out-migration rate, voluntary out-migration rate | Per capita income (+/·), Tuition fee in-state colleges (+/+), in-state public colleges (–/–), in-state student aid (·/·) |
| MCHUGH and MORGAN (1984) | 1974 | Flows, US states | Migration level | Per capita income orig. (+), per capita income dest. (+), growth rate employment orig. (·), growth rate employment dest. (+), non-student migration orig. (+), college freshman orig. (+), resident tuition orig. (·), non-resident tuition dest. (·), private tuition orig. (+), distance (–), distance to all other states (+), high selectivity dest. (+), low selectivity dest. (+), high selectivity orig. (·), low selectivity orig. (·) |
| ISHIKAWA (1985) | 1985 | Flows, Japanese prefectures | Migration level | Origin-specific distance (–), origin-specific accessibility university (– for 17 and + for 31 regions) |
| MIXON (1992a) | 1986 | US states | Voluntary out-migration rate | Average college tuition (+), pacific location (·), Ivy League (·), overall quality state college (–), climate (·), per capita public higher education funds (·), per capita income (·) |
| MIXON (1992b) | 1989 | US states | Voluntary out-migration rate[2] | Tuition (+), quality (–), per capita income (·) |
| MIXON and HSING (1994a) | 1990 | US institutions | Percentage out-of-state enrolment[3] | University enrolment (·), entrance difficulty (–), NCAA athletic participation (–), private university (+), considered black (+), student-faculty ratio (–), faculty with PhD (·) |
| MIXON and HSING (1994b) | 1990 | US institutions | Percentage out-of-state enrolment | University enrolment (·), entrance difficulty (–), NCAA athletic participation (–), private university (+), considered black (+), student-faculty ratio (–) |
| KYUNG (1996) | 1986 | Inflow US states to NY state | Out-of-state enrolment in NY[4] | Educational expenditures in public institutions (·), SAT score (+), per capita income (+), admission rate public institutions (–), high school graduates (+), distance (–) |
| BARYLA and DOTTERWEICH (2001) | 1998 | US institutions | Percentage non-resident student enrolment[5] | Tuition (+/+/+/+), public institution (–/–/–/–), enrolment (·/–/–/·), top selectivity (+/+/+/+), very selectivity (+/+/+/+), competitive selectivity (·/·/·/·), metropolitan area (–/·/·/–), unemployment (–/–/·/–), per capita income (·/–/+/–) |
| FLORAX *et al.* (2003) | 1970, 1982, 1994 | Regions, The Netherlands, UK and Sweden | First-time entrants[6] | Eligible age group (+), population with higher education (+), per capita income (·), unemployment (+), urbanisation (?), accessibility (+ in Sweden for 1970s and 80s, otherwise ·) |

*Notes:*
1. See Note 1 to Table 1A. Multiple results refer to different dependent variables (TUCKMAN, 1970) or different sub-areas of the US (BARYLA and DOTTERWEICH, 2001).
2. Study based on a recursive three-equation model. Results for the migration equation are presented.
3. Study based on a two-equation model. Results for the migration equation are presented.
4. The model is estimated for undergraduates, professionals and graduates. Results for undergraduates are presented.
5. We only report here the results for the non-resident student enrolment model.
6. The model is estimated for three countries, with region-specific coefficients for university and non-university regions, and a time- and region-specific coefficient for the accessibility variable for The Netherlands and Sweden. We provide an overall indication of the significance and sign of the coefficients; see the original study for more details.

*Table 2. Continuous explanatory variables with explanation,*[1] *descriptive statistics and hypothesised direction of the effect*

| Variable | Explanation | Mean | Standard deviation | Hypothesised direction of effect |
|---|---|---|---|---|
| Distance | Distance over the road in km between points in region *i* and university region *j* with the highest population density | 139.82 | 77.00 | – |
| Quality | Composite index of university quality for the university located in region *j* | 1.24 | 0.90 | + |
| | Student-teacher ratio of the university located in region *j* | 3.26 | 1.26 | – |
| Urbanisation | Degree of urbanisation in university region *j*, operationalized as population density (persons per $km^2$) | 793 | 385 | + |
| Rent | Rent in university region *j*, based on the average basic rent of houses | 694.00 | 27.98 | – |
| Scope | Scope of the university in region *j*, operationalized as the number of study programmes | 50.54 | 33.86 | + |
| Centrality | Centrality index in university region *j* | 2,129 | 668 | ? |

*Note:* 1. See the main text for more details and sources.

*Table 3. Estimation results for three different specifications of the production-constrained gravity model with homogeneous coefficients (Baseline) and with origin-specific distance coefficients*[1]

| Variables | Specification I | | Specification II | | Specification III | |
|---|---|---|---|---|---|---|
| | Baseline | Orig.-specific distance | Baseline | Orig.-specific distance | Baseline | Orig.-specific distance |
| Distance | -1.2455* (0.0657) | negative significant | -1.3386* (0.0737) | negative significant | -1.3130* (0.0749) | negative significant[2] |
| Quality (composite index) | | | -0.4248* (0.0579) | -0.4162* (0.0532) | — | — |
| Quality (student-teacher ratio) | | | — | — | -0.1281 (0.1254) | -0.0334 (0.1171) |
| Urbanisation | | | 0.4004* (0.0884) | 0.4144* (0.0820) | 0.5253* (0.1251) | 0.5914* (0.1197) |
| Rent | | | -2.5928** (1.1159) | -1.9940*** (1.1093) | -5.7665* (1.1419) | -5.3624* (1.1064) |
| Scope | | | 0.1306* (0.0417) | 0.1327* (0.0411) | 0.2702* (0.0433) | 0.2714* (0.0416) |
| Centrality | | | -1.5878* (0.1690) | -1.7686* (0.1597) | -0.5429* (0.2004) | -0.8430* (0.1851) |
| $R^2$ | 0.52 | 0.59 | 0.62 | 0.69 | 0.59 | 0.66 |
| *BP* | 8.62* | 60.87** | 97.16* | 102.97* | 84.95* | 83.96* |

*Notes:* 1. Significance at the 1, 5 and 10% level is indicated with *, ** and ***, respectively, and White-adjusted standard errors are given in parentheses. Note that the $R^2$ statistic is not bound to the usual interval because the specification does not contain a constant term. *BP* refers to the OLS-based results of the Breusch-Pagan test for homoskedasticity, which has a $\chi^2$-distribution with the degrees of freedom equal to the number of regressors.

2. See also Fig. 6.

*Table* 4. *Estimation results for three different specifications of the production-constrained gravity model with university-specific distance coefficients*[1]

| Variables[2] | Specification I | Specification II | Specification III[3] |
|---|---|---|---|
| LEI | -1.3274* | -1.4497* | -1.3357* |
| | (0.1631) | (0.1693) | (0.1656) |
| RUG | -1.2929* | -1.4365* | -1.4092* |
| | (0.1673) | (0.1209) | (0.1286) |
| UU | -1.7385* | -1.7350* | -1.9492* |
| | (0.2697) | (0.3014) | (0.3494) |
| EUR | -1.3428* | -1.4863* | -1.4623* |
| | (0.0712) | (0.0876) | (0.0823) |
| TUD | -0.6609* | -0.4999* | -0.5810* |
| | (0.0792) | (0.1079) | (0.0856) |
| TUE | -1.7706* | -1.7833* | -1.7682* |
| | (0.3813) | (0.4040) | (0.3817) |
| UT | -1.0413* | -1.1797* | -1.3520* |
| | (0.1490) | (0.2309) | (0.3185) |
| WUR | -0.1213 | -0.3333*** | -0.3183*** |
| | (0.2640) | (0.1756) | (0.1807) |
| UM | -0.7695* | -0.9548* | -0.6796* |
| | (0.0718) | (0.1159) | (0.1440) |
| UvA | -1.8654* | -1.6882* | -1.8324* |
| | (0.1291) | (0.1168) | (0.1312) |
| VU | -1.6368* | -1.7506* | -1.5572* |
| | (0.1220) | (0.1385) | (0.1202) |
| KUN | -1.6868* | -1.6980* | -1.6739* |
| | (0.3045) | (0.3004) | (0.3112) |
| KUB | -2.0749* | -2.0714* | -2.0719* |
| | (0.4445) | (0.3793) | (0.3887) |
| Quality | | -0.4102* | — |
| (composite index) | | (0.0610) | |
| Quality | | — | -0.1773 |
| (student-teacher ratio) | | | (0.1221) |
| Urbanisation | | 0.2811* | 0.3452** |
| | | (0.0909) | (0.1421) |
| Rent | | -2.8537* | -6.4124* |
| | | (1.3027) | (1.2168) |
| Scope | | 0.1480* | 0.2925* |
| | | (0.0447) | (0.0445) |
| Centrality | | -1.3221* | -0.1630 |
| | | (0.1742) | (0.2353) |
| $R^2$ | 0.60 | 0.69 | 0.66 |
| *BP* | 25.03** | 94.80* | 111.11* |

*Notes:* 1. See note 1 to Table 3.
2. See Fig. 1 for the meaning of the university abbreviations.
3. See Fig. 7 for a graphical representation of the university-specific distance decay coefficients.

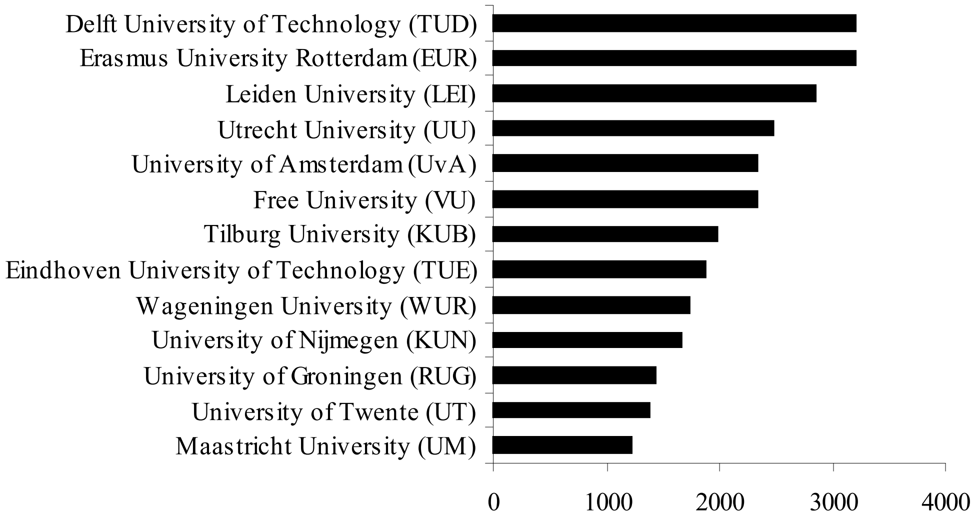


*Fig*. 1. *Centrality index for Dutch universities, in 2000*
*Note:* Computed on the basis of data from VSNU (2000).

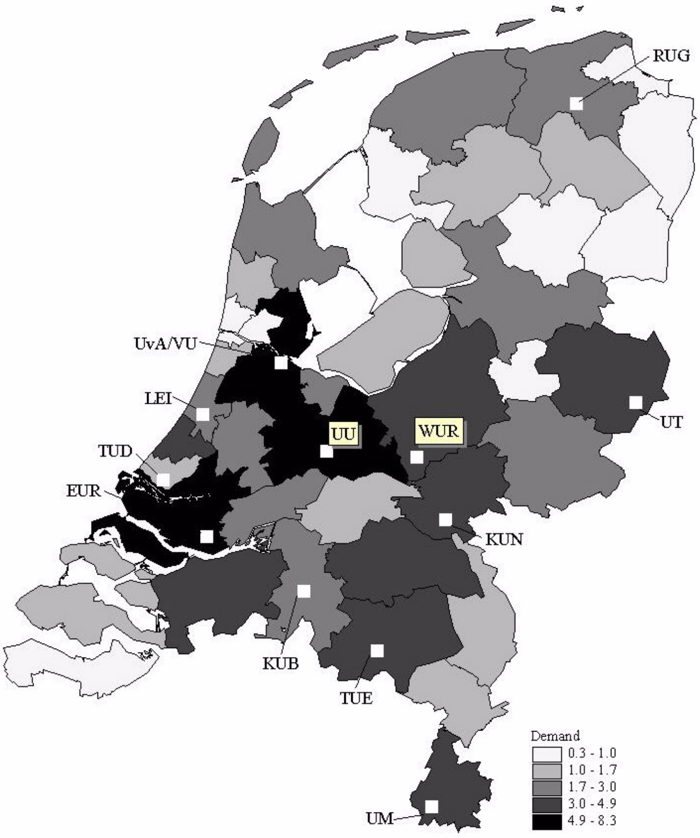


*Fig.* 2. *Map of the regional demand for higher education, defined as the percentage of first-year students per COROP region as to the total number of first-year students in 2000, and the location of universities*
*Note:* See Fig. 1 for the meaning of the university abbreviations. Computed on the basis of data from IBG (2000).

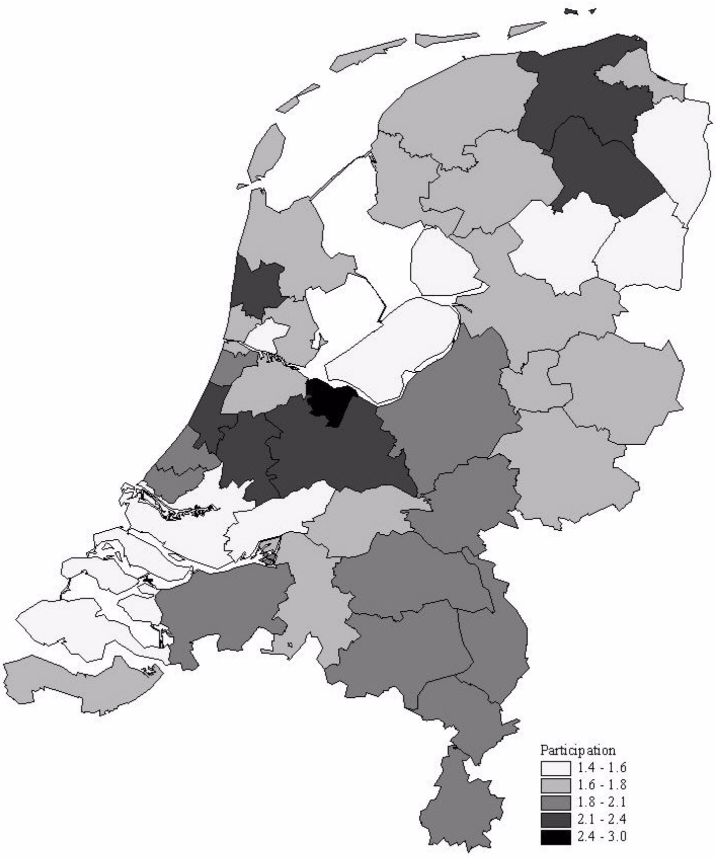


*Fig.* 3. *Map of the regional participation rate, defined as the number of first-year students per 1,000 in the population for COROP regions, in 2000*
*Note:* The number of first-year students is taken from IBG (2000) and the population figures from CBS (2000a).

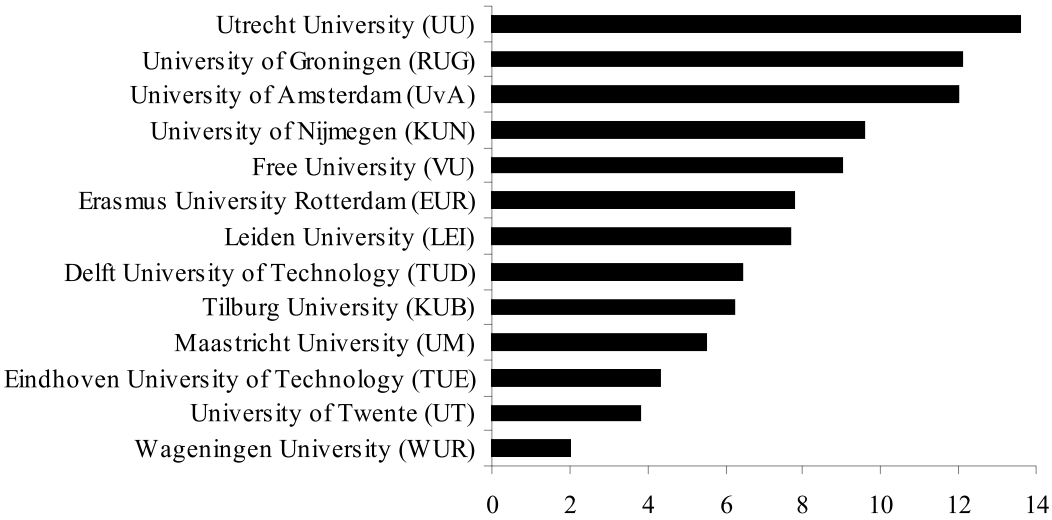


*Fig.* 4. *Institutional market share, defined as the percentage first-year students per university as to the total number of first-year students, in 2000*
*Note:* Computed using data from IBG (2000).

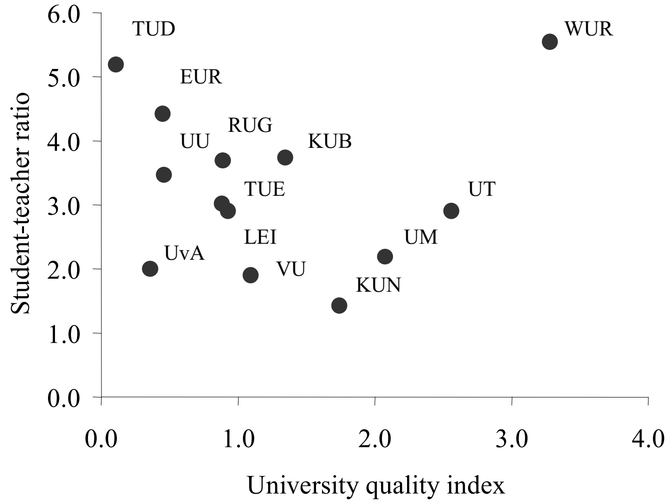


*Fig. 5. Scatterplot of the student-teacher ratio versus the quality index for Dutch universities, in 1999*
*Note:* See Fig. 1 for the meaning of the university abbreviations. Computed using the ELSEVIER (1999) data on quality and VSNU (2000) data on the student-teacher ratio.

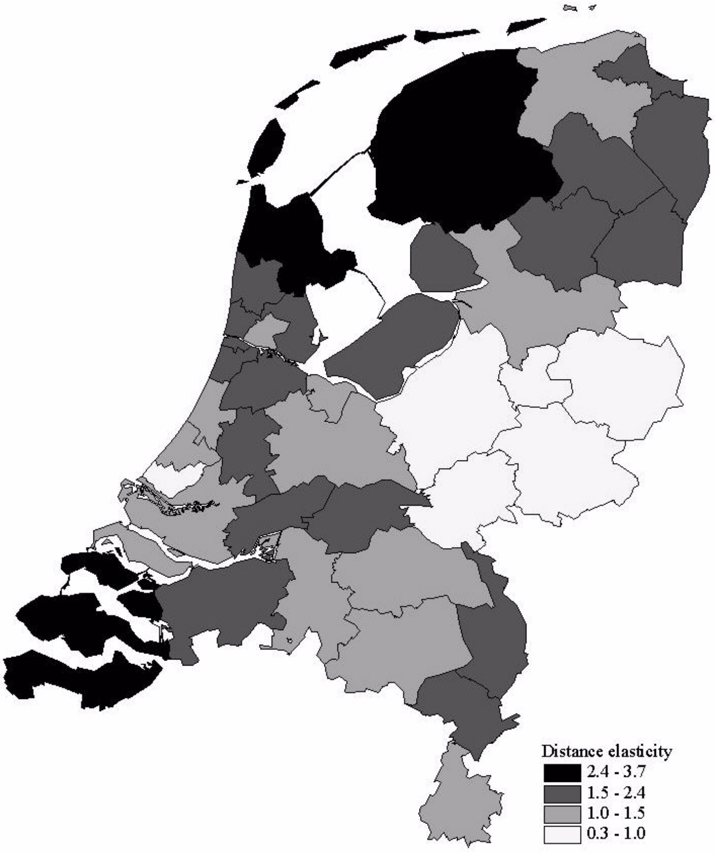


*Fig. 6. Map of the absolute value of the (negative) origin-specific distance decay elasticity of the demand for first-year university education in COROP regions, in 2000*
*Note:* Based on the detailed estimation results for Specification III, in Table 3.

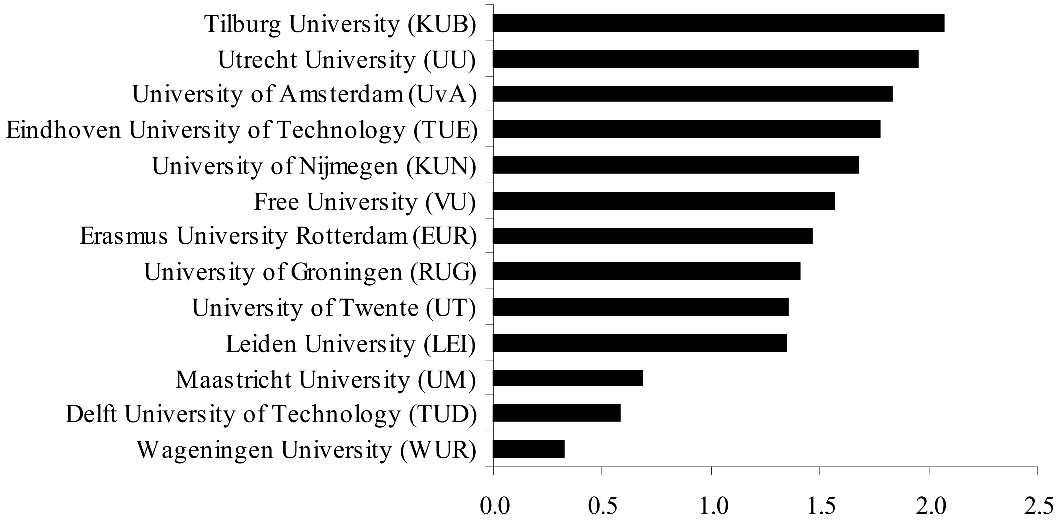


*Fig. 7. Absolute value of the (negative) university-specific distance decay elasticity of the demand for first-year university education in COROP regions, in 2000*

*Note:* Based on the detailed estimation results for Specification III, in Table 4.